BMDO Cost Risk Improvement in Operations and Support (O&S) Estimates

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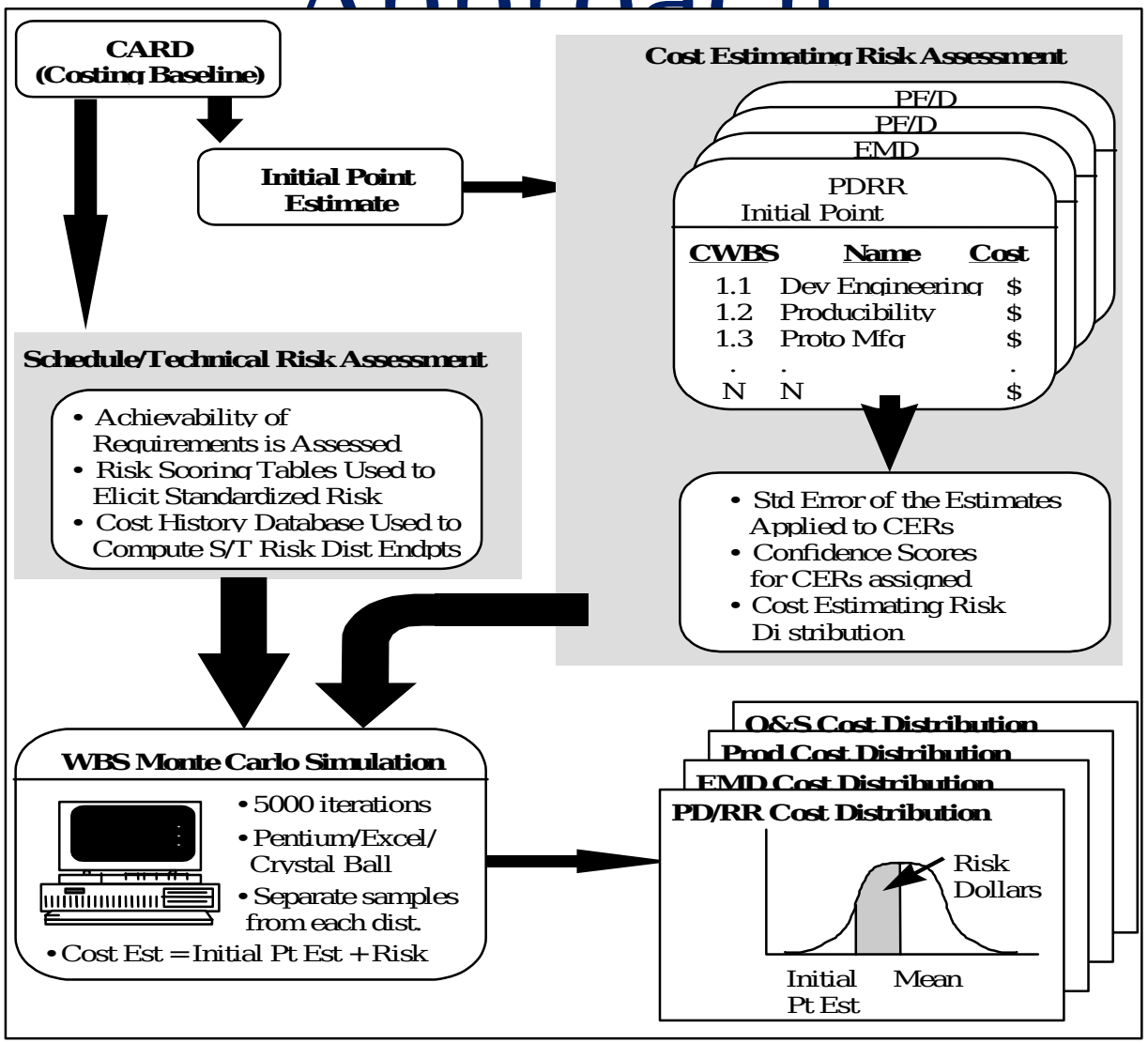
Outline

- Purpose
- Overview of BMDO Cost Risk Methodology
- Issues with Risk in O&S
- Ideas for improvement
- Implementation
- Analysis of Results
- Conclusion

Purpose

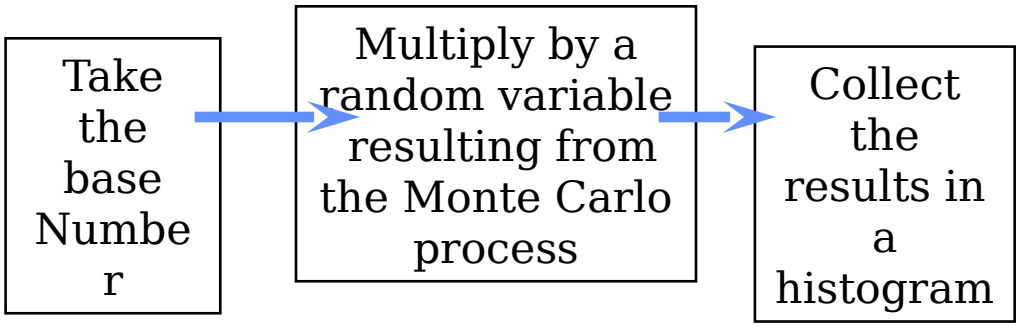
- Research done for, and funded by the Ballistic Missile Defense Organization (BMDO) under direction of Ms. Donna Snead and Mr. Lowell Naef.
- Purpose was to further enhance BMDO Cost Risk Model, which has been used to develop independent life cycle cost risk assessments since 1989
  - Model is currently well received, however there are some recognized weaknesses that await further research. One such area is the capability for quantifying risk in O&S.
  - The focus of this paper will be to examine ways reflect more accuracy in O&S cost risk estimates.

BMDO Cost Risk Approach

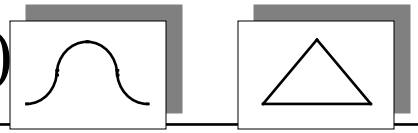


BMDO Cost Risk Model

Steps:


Take the base Numbe r
Multiply by a random variable resulting from the Monte Carlo process
Collect the results in a histogram

Example (one iteration)



WBS	Initial Point Estimate	CE	S/T draw	Estimate draw with Risk
1.0 Hardware	100M			127M
1.1 Item 1	80M	1.1	1.15	100M
1.2 Item 2	20M	1.15	1.2	27M
2.0 SW	10M		1.03	1.3
3.0 SE/PM	11M			14M
Total	121M			168M

Some elements are roll-ups

Some elements are factors off of others

The result is an estimate with risk

BMDO Cost Risk Model

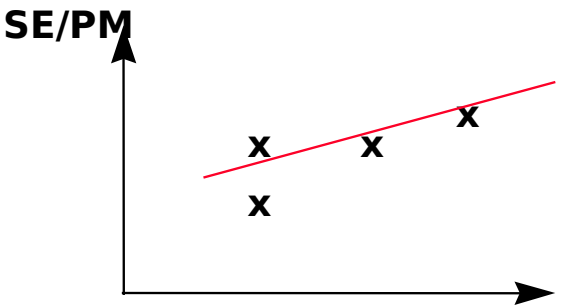
Functional Correlation[1]

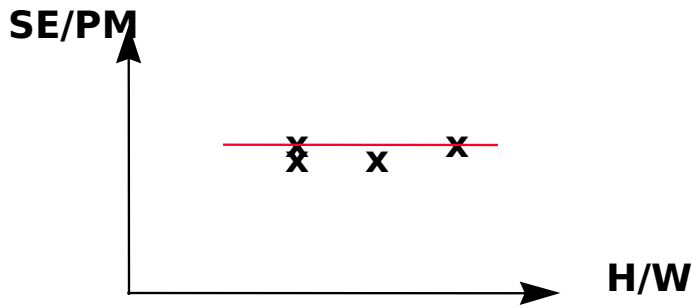
Suppose SE/PM = a * Hardware

a = .1, with Standard Deviation of .01

H/W = 100, with Standard Deviation of 10

	Drawn Variables	Functional Correlation	Without Correlation
Iteration 1	**H/W = 100 a = .09**	**SE/PM = 9**	**SE/PM = 9**
Iteration 2	**H/W = 110 a = .10**	**SE/PM = 11**	**SE/PM = 10**
Iteration 3	**H/W = 90 a = .11**	**SE/PM = 9.9**	**SE/PM = 11**
Iteration 4	**H/W = 90 a = .09**	**SE/PM = 8.1**	**SE/PM = 9**





1 *An Overview of Correlation and Functional Dependencies in Cost Risk and Uncertainty Analysis,* DoDCAS 1994, R. L. Coleman, S. S. Gupta

Should We Have Risk in O&S?

- We know:
  - O&S Cost is correlated to Acquisition Hardware/Software, (e.g. SW Maintenance, spares, etc.)
  - Correlation of cost growth exists between the R&D and Production phases of Acquisition[1]
- We believe: this implies correlation in cost *growth* between O&S and Acquisition from onset
  - Note, this does not mean cost growth during O&S
  - Intuitive, though no data analysis to support

1 Cost Risk Estimates Incorporating Functional Correlation, Acquisition Phase Relationships, and Realized Risk, SCEA National Conference 1997, R. L. Coleman, S. S. Gupta, J. R. Summerville, G. E. Hartigan

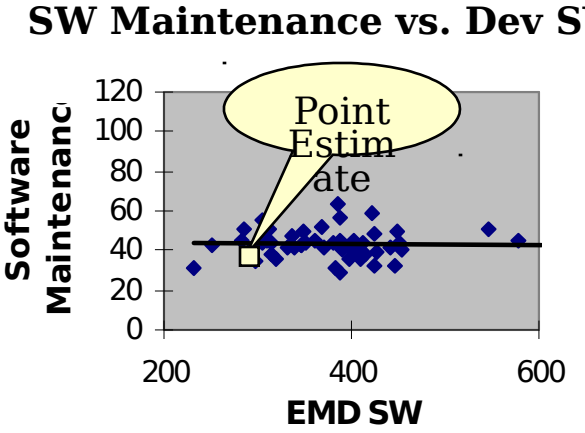
Issues with BMDO O&S Risk

- Most BMDO elements currently have little to no sched/tech risk in O&S
  - Compare Risk % and CV w/other phases
  - Lack of correlation is the culprit

	Pt Est	Mean	CV	Risk $	Risk %	CE Risk	S/T Risk
LCC	5392.64	6,262.92	0.12	870.28	16.1%	3.6%	12.6%
PDRR	241.11	274.24	0.11	33.13	13.7%	2.4%	11.3%
EMD	1226.11	1,491.47	0.12	265.36	21.6%	3.3%	18.4%
LRIP	230.65	272.75	0.17	42.10	18.3%	3.7%	14.6%
Prod-Missile	2494.12	2,940.70	0.17	446.59	17.9%	3.9%	14.0%
Prod-Ships	609.53	668.18	0.35	58.66	9.6%	3.3%	6.3%
O&S	567.72	588.18	0.13	20.46	3.6%	3.6%	0.0%
D&D	23.40	27.40	0.24	4.00	17.1%	3.9%	13.2%

Numbers are for example only

Example:



As Dev SW increases, SW Maint should as well, causing a higher mean, and thus a higher risk percentage. Lack of correlation holds down the SW Maint cost here.

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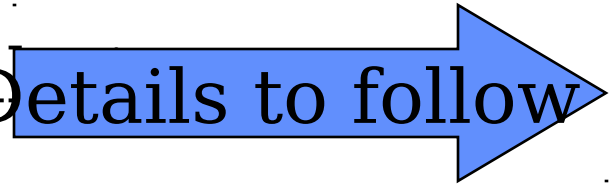
Ideas for Improvement

- Use Functional Correlation[1] where available
- Expand on Functional Correlation using the following methods:
  - Cost Response Curves
  - Injected Correlation
  - Algebraic manipul

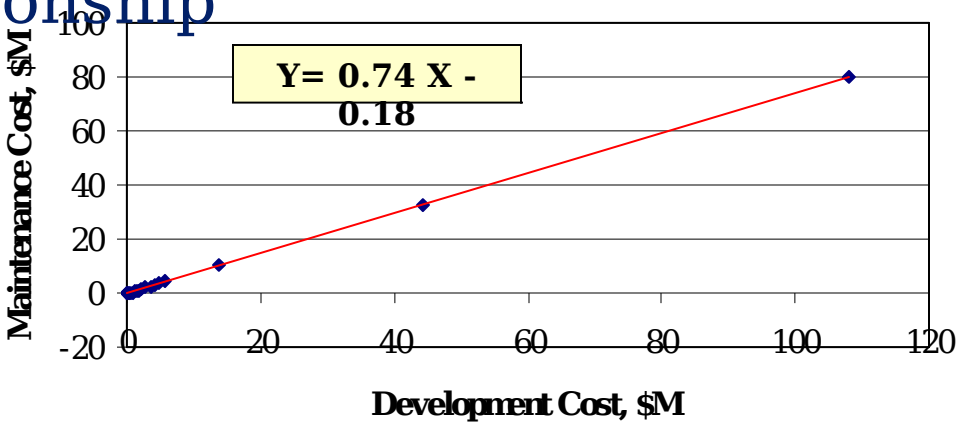


1 Cost Risk Estimates Incorporating Functional Correlation, Acquisition Phase Relationships, and Realized Risk, SCEA National Conference 1997, R. L. Coleman, S. S. Gupta, J. R. Summerville, G. E. Hartigan;
An Overview of Correlation and Functional Dependencies in Cost Risk and Uncertainty Analysis, DoDCAS 1994**,** R. L. Coleman, S. S. Gupta

Cost Response Curves[1]

- Use existing cost tools to create a functional relationship
  - E.g. for Software: SLIM, SEER, SASET
  - Run several iterations on different SLOC values to derive an equation that links maintenance cost to development cost
  - Incorporate in cost model as a functional relationship

Example:



1 Cost Response Curves - Their generation, their use in IPTs, Analyses of Alternatives, and Budgets, DoDCAS 1996, K. J. Allison, K. E. Crum, R. L. Coleman, R. G. Klion

Injected Correlations

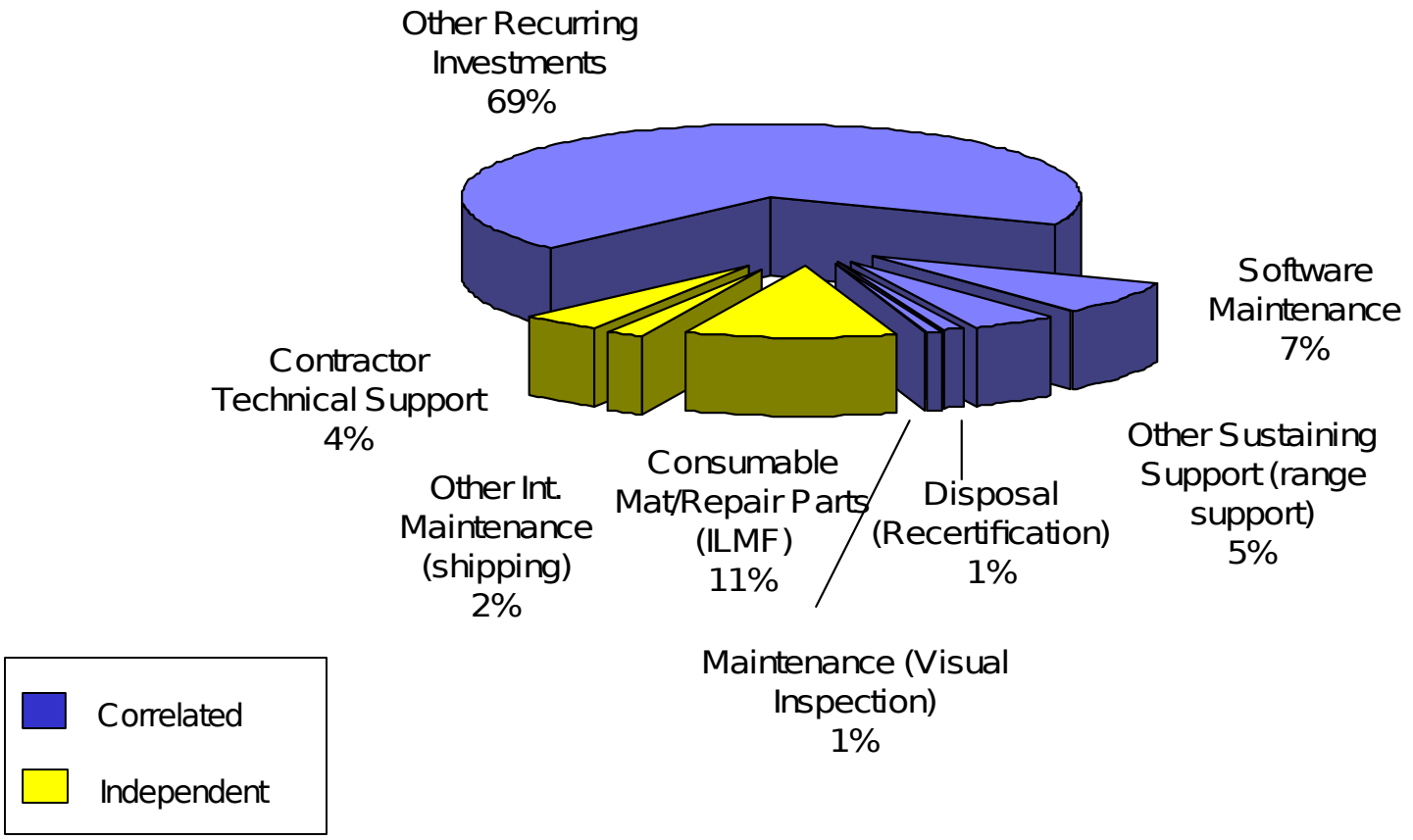
- Setup links to create correlation *implicitly*
  - Correlation coefficients are not estimated directly
  - Procedure involves linking cost growth factors between elements, and creating correlation in the simulation as a result
  - The amount of correlation you have implicitly estimated can be calculated after the simulation has

Other Approaches

- Other extensions of Functional Correlation are possible
- Similar to the CRC, FC may be applied if there is a CER that is related to a common variable in Acquisition, e.g. weight.
  - This case involves simple algebraic manipulation of the O&S equation in order for it to reference the resulting cost of the related CER rather than its common parameter

Implementation

Navy Area O&S Breakdown

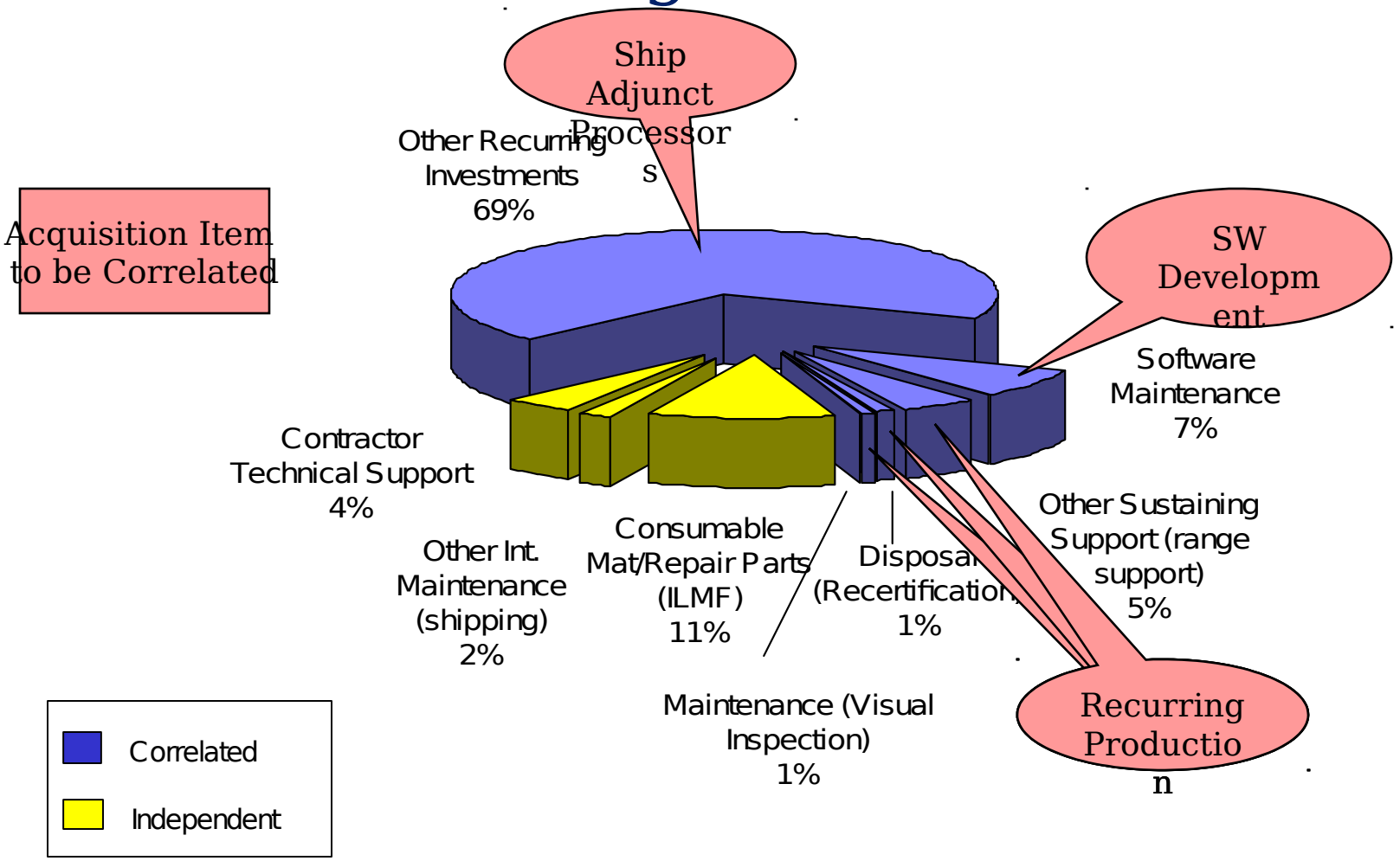


O&S Model Adjustments

- Before: 1% of O&S phase Correlated to Acquisition
- After: 89% of O&S phase Correlated to Acquisition
- Used functional relationships where possible
  - Disposal, spares
- Injected correlation in cases where functions not available
  - SW Maintenance, Intermediate Maintenance

Navy Area O&S Breakdown

Directing Correlation



Risk in Navy Area O&S

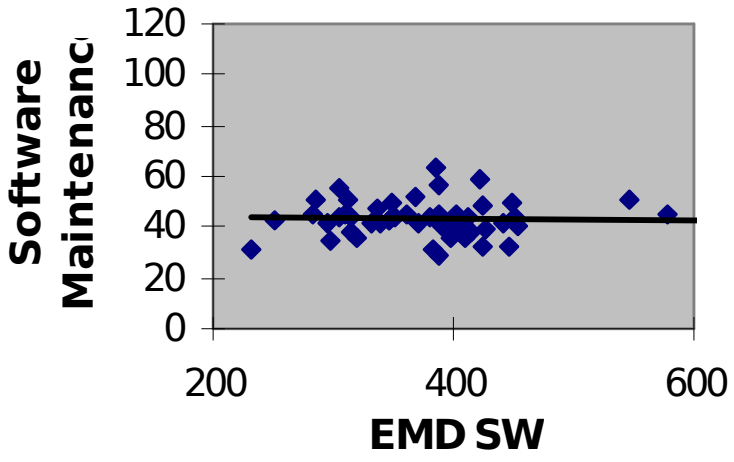
Before and After

	Point	Phase	Correlated	Original Model			New Test Model		
	Estimate	Portion	to	Mean	Risk %	CV	Mean	Risk %	CV
TOTAL	**567.72**	**100%**		**588.18**	**3.6%**	**0.13**	**621.23**	**9.4%**	**0.23**
Maintenance (Visual Inspection)	3.99	1%	Missile Recurring Production	4.14	3.6%	0.19	4.75	18.9%	0.25
Consumable Mat/Repair Parts (ILMF)	25.96	11%	Missile Recurring Production	26.70	2.8%	0.19	30.70	18.3%	0.25
Other Int. Maintenance (shipping)	10.38	2%	nothing	10.78	3.9%	0.19	10.70	3.1%	0.19
Contractor Technical Support	24.05	4%	nothing	24.83	3.3%	0.19	24.69	2.7%	0.20
Other Recurring Investments	391.36	69%	Ship HW (Adjunct Processors)	404.91	3.5%	0.19	420.50	7.4%	0.33
Software Maintenance	42.08	7%	EMD SW	43.61	3.6%	0.19	56.85	35.1%	0.27
Other Sustaining Support (range support)	64.30	5%	nothing	66.61	3.6%	0.15	66.46	3.4%	0.15
Disposal (Recertification)	5.60	1%	Missile & Ship Recurring HW	6.59	17.9%	0.25	6.58	17.6%	0.26

Correlation Example
SW Maintenance

Actual Simulation Results

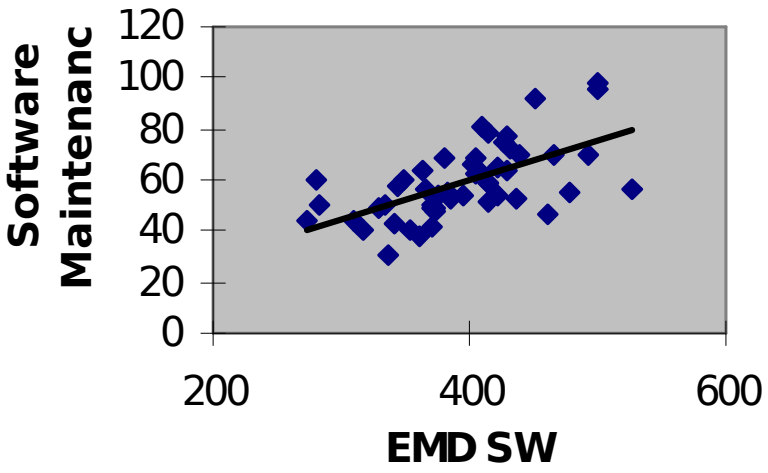
Before:



Not Correlated

Risk = 3.6%

After:

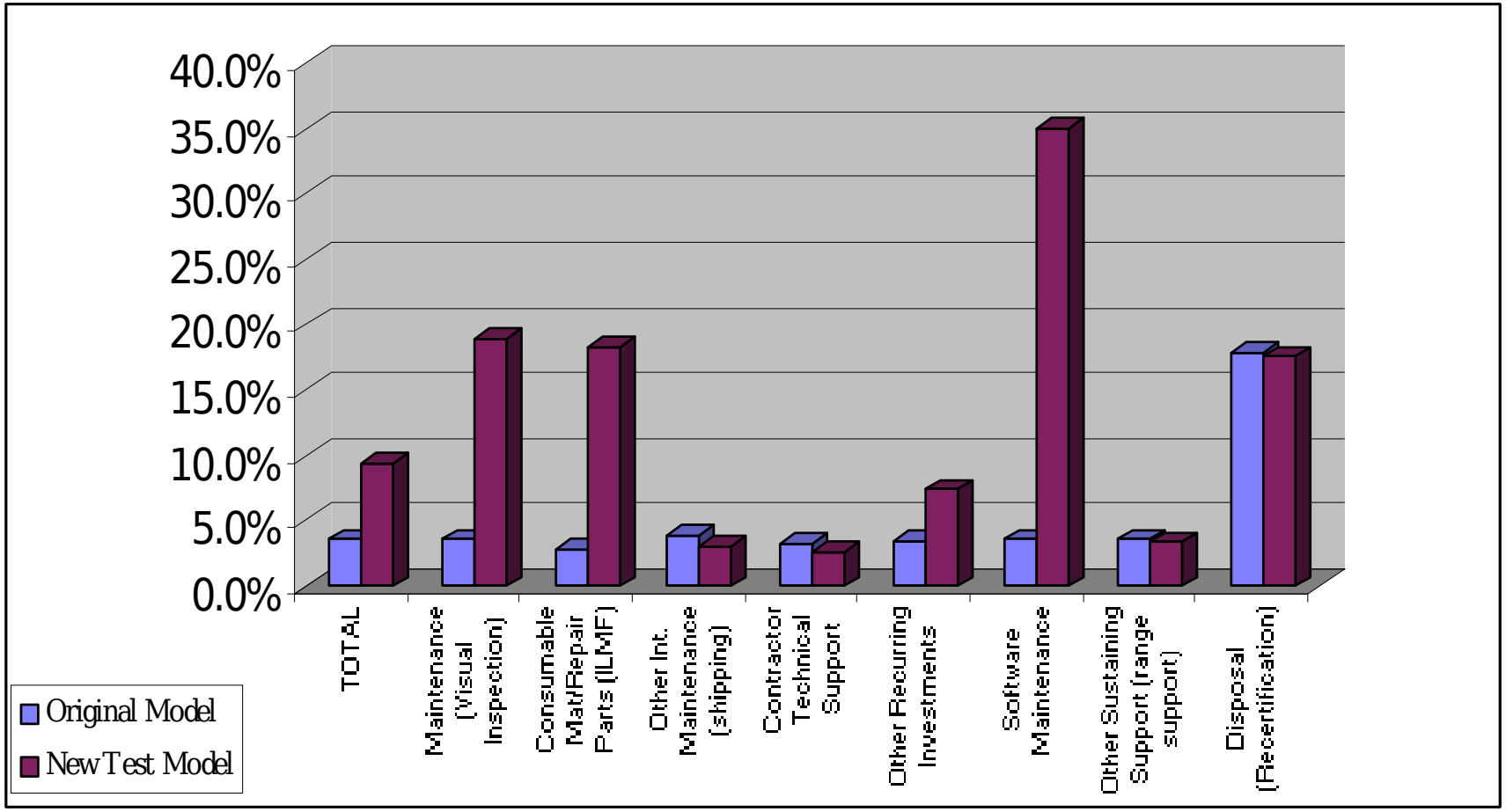


Correlated

Risk = 35.1%

Risk % in Navy Area O&S

Before and After



Navy Area Risk

Navy Area Risk Results

Before O&S Revamp

	Pt Est	Mean	CV	Risk $	Risk %	CE Risk	S/T Risk
LCC	5392.64	6,262.92	0.12	870.28	16.1%	3.6%	12.6%
PDRR	241.11	274.24	0.11	33.13	13.7%	2.4%	11.3%
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O&S	567.72	588.18	0.13	20.46	3.6%	3.6%	0.0%
D&D	23.40	27.40	0.24	4.00	17.1%	3.9%	13.2%

After O&S Revamp

	Pt Est	Mean	CV	Risk $	Risk %	CE Risk	S/T Risk
LCC	5392.64	6,300.64	0.12	908.00	16.8%	3.6%	13.3%
PDRR	241.11	274.20	0.11	33.09	13.7%	2.4%	11.3%
EMD	1226.11	1,491.05	0.12	264.95	21.6%	3.3%	18.3%
LRIP	230.65	272.80	0.17	42.14	18.3%	3.7%	14.6%
Prod-Missile	2494.12	2,944.59	0.17	450.47	18.1%	3.9%	14.2%
Prod-Ships	609.53	669.54	0.36	60.01	9.8%	3.3%	6.5%
O&S	567.72	621.23	0.23	53.51	9.4%	3.6%	5.8%
D&D	23.40	27.22	0.24	3.82	16.3%	3.9%	12.5%

Analysis

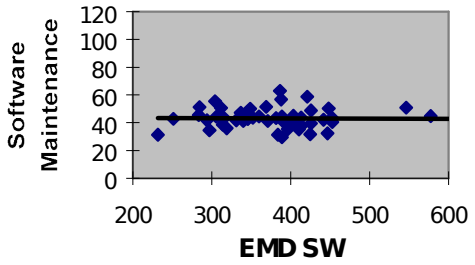
- Risk increased for all newly correlated items
- Total percent still seems understated when compared to other phases--why?
  - Bulk of Phase $ (69%) under “Other Recurring Investments”
    - Cost is for periodic replacement of ship adjunct processors
    - Correlated to adjunct processor HW in the ship production phase, low risk
  - Note new O&S risk % close to Ship Production risk %

Resulting Correlation

BEFORE

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.02
R Square	0.0004
Adjusted R Square	-0.02
Standard Error	7.24
Observations	50



ANOVA

	df	*SS*	*MS*	*F*	*Sig F*
Regression	1	0.901121	0.901121	0.017168	0.896303
Residual	48	2519.504	52.48967		
Total	49	2520.405			

	Coeffs	*Std Error*	*t Stat*	*P-value*	*Low 95%*	*Up 95%*
Intercept	43.80	5.40	8.11	1.5E-10	32.94	54.65
EMD SW	0.00	0.01	-0.13	0.90	-0.03	0.03

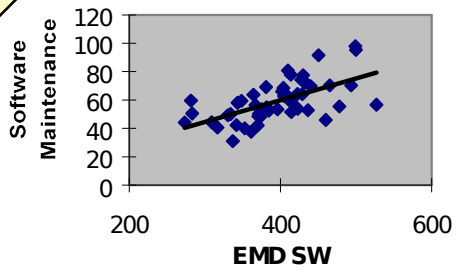
Software Maintenance Example

ρ = 0.61

AFTER

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.61
R Square	0.38
Adjusted R Square	0.36
Standard Error	11.49
Observations	50



ANOVA

	df	*SS*	*MS*	*F*	*Sig F*
Regression	1	3,835.11	3,835.11	29.03	0.000002
Residual	48	6,341.72	132.12		
Total	49	10,176.83			

	Coeffs	*Std Error*	*t Stat*	*P-value*	*Low 95%*	*Up 95%*
Intercept	-1.87	11.41	-0.16	0.87	-24.82	21.08
EMD SW	0.15	0.03	5.39	0.00	0.10	0.21

This is not to say we have confidence that these results exactly reflect reality, but it is clearly a better alternative than what was previously accepted

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Conclusion

- The methodology presented in this paper has significantly enhanced the quality of BMDO O&S cost estimates
  - Concepts are simple to implement
  - All required assumptions can feasibly be made by cost analysts
- Future improvements will result with the development of better CERs for O&S that provide known relationships with Acquisition.